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SPECIFICATION FOR 32·768 kHz QUARTZ CRYSTAL UNITS FOR WRIST WATCHES

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 5

May 1983

Indian Standard

SPECIFICATION FOR 32·768 kHz QUARTZ CRYSTAL UNITS FOR WRIST WATCHES

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Sectional Committee, LTDC 12

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(*Continued on page* 2)

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(*Continued from page* 1)

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Indian Standard

SPECIFICATION FOR 32·768 kHz QUARTZ CRYSTAL UNITS FOR WRIST WATCHES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 18 October 1982, after the draft finalized by the Piezoelectric Devices for Frequency Control and Selection Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 The object of this standard is to specify the requirements for 32·768 kHz quartz crystal units for wrist watches. This standard describes the test methods for these crystal units.

0.3 While preparing this standard, assistance has been derived from IEC Pub 689-1980 'Measurements and test methods for 32 kHz Quartz crystal unit for wrist watches and standard values' issued by the International Electrotechnical Commission.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers test methods and requirements of 32·768 kHz quartz crystal units for wrist watches.

2. TERMINOLOGY

2.0 For the purpose of this standard, the terms and definitions covered in IS : 1885 (Part XLIV)-1978† shall apply.

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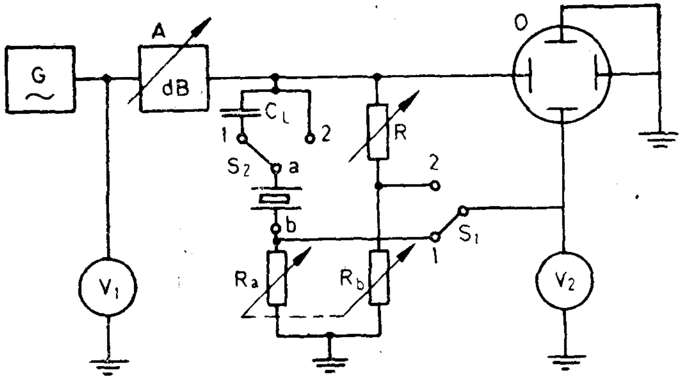
*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary : Part XLIV Piezoelectric devices.

3. TEST METHODS FOR THE ELECTRICAL PARAMETERS

3.1 Measurement of Resonance Frequency f_r and Load Resonance Frequency F_L.

3.1.1 When a circuit or an integrated oscillator is used, the measurement conditions shall be such that the results are identical to those obtained with the reference circuit (*see* Fig. 1), where G is a frequency synthesizer and R is an adjustable reference resistance.



NOTE — If S_2 is in position 2, the resonance frequency f_r. Can be measured; if s_2 is in position 1, the measurement of the frequency f_L.

FIG. 1 CIRCUIT FOR MEASUREMENT OF RESONANCE FREQUENCY f_r AND LOAD RESONANCE FREQUENCY f_L

Voltages across R_a and R_b are measured with the voltmeter V_2. The phase difference between the signal applied to the bridge and the signal across R_a or R_b is indicated on the oscilloscope *0* or phase meter. The use of phase meter instead of an oscilloscope makes it possible for better measurement accuracy to be obtained.

3.1.2 An important sources of stray capacitance to ground that shall be considered occurs at the junction of the crystal unit and the capacitor C_L. Consideration shall be given to the stray capacitance of each terminal of the crystal unit to the earth. When the magnitude of this stray reactance is large compared with the magnitude of the terminating impedance, the distributed capacitance to earth of the crystal unit and the distributed capacitance to ground of C_L at the junction may be treated to a first approximation as being in parallel with C_L [*see* IS : 7962-1975*] :

a) Select $R_a = R_b \ll R_r$ (resonance resistance of the crystal unit),

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*Methods of measurement for piezoelectric vibrators operating over the frequency range up to 30 MHz.

b) Adjust the drive level with attenuator *A*,

c) Adjust the frequency of synthesizer *G* until the Lissajous figure on the oscilloscope indicates a zero phase difference (switch S_1 in position 1) or $\phi = 0$ on a phase meter, and

d) Read the frequency of synthesizer *G*.

3.1.3 *Conditions of Measurement* — The following conditions of measurement shall apply :

a) Enclosure not earthed,

b) Measuring socket shall not introduce any mechanical stress on the quartz crystal unit which could cause frequency changes,

c) The synthesizer shall have a frequency resolution of at least 10 MHz,

d) *Temperature* — In the worst case (turnover point at 33°C; measurement at 21°C); the slope, at *T*°C, is about 1×10^{-6}/°C. *T*°C is specified in Appendix A.

e) *Load capacitance* C_L — The tolerance on the load capacitance should be that value which results in a frequency change not exceeding 10 percent of the frequency tolerance at the reference temperature or 1 percent of the nominal load capacitance, whichever is smaller. The capacitance C_L of Fig. 1 consists of the capacitance of the mechanical tool used for the measurement and a series capacitor added to obtain one of the different values of C_L proposed in Appendix A. The series capacitor added shall be as near as possible to the crystal unit. The accuracy of the measurement depends on this, and

f) *Measuring level* — When only the voltage is given, the following formula may be used:

$$P = \frac{V^2}{R_r}$$

where

R_r is measured according to **3.2.1**,

V is the rms value of the voltage at resonance frequency across the terminals of the crystal unit,

P is specified in Appendix A.

3.2 Measurement of Resonance Resistance R_r

3.2.1 *Measurement* — The crystal unit shall be measured without load capacitance C_L. If the reference network is used:

a) adjust the frequency of G to obtain the maximum voltage across R_a as indicated by V_2;

b) connect V_2 to R_b (S_1 in position 2), and adjust R to obtain the same level on V_2 as given in (a); and

c) the Lissajous figure on the oscilloscope shall indicate a zero phase difference or $\phi = 0$ on the phase meter.
Then $R = R_r$.

3.2.2 *Measuring Conditions* — *See* Appendix A.

3.3 Determination of the Turnover Point and Parabolic Coefficient β (Standard Reference Method)

3.3.1 It is to be measured at least five points. In general, the theoretical turnover point and four points symmetrically located and near the first one are considered.

The frequency is measured according to **3.2.1** but without load capacitance C_L. The measurement accuracy shall be better than $\pm 0{\cdot}5 \times 10^{-6}$ and the temperature shall be controlled to ± 0·3°C and measured within ± 0·1°C.

The temperature stabilization time shall be about 30 min for each measurement.

The turnover point and the parabolic coefficient β, are obtained by computation (for example, linear regression).

In the worst case, the error on the determination of the turnover point is ± 1°C.

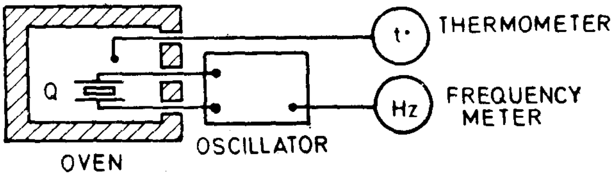
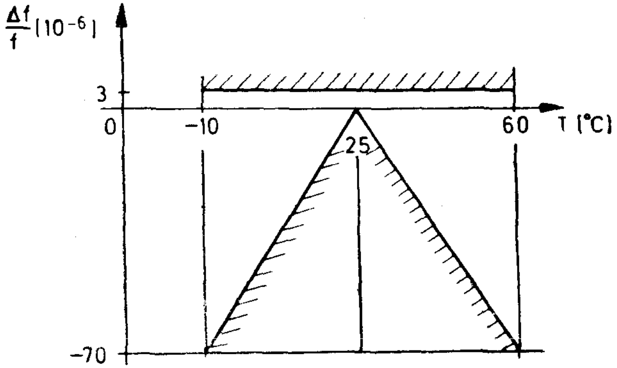


FIG. 2 MEASUREMENT OF TURNOVER POINT AND PARABOLIC COEFFICIENT

3.3.2 Measurement of the Frequency Versus Temperature Characteristics (Mass Production Method) — When it is not necessary to determine the turnover temperature, the measurement of frequency at three points is sufficient to have a good idea of the frequency behaviour with temperature.

The limiting points of the operating temperature range are chosen (− 10°C, + 60°C), as well as reference temperature.

The frequency variation shall remain within the limits of Fig. 3 for the stated values of β and the turnover point.



frequency-temperature template
(turnover point: 25 ± 8°C, $\beta = 45 \times 10^{-9}/°C^2$)

FIG. 3 MEASUREMENT OF FREQUENCY VERSUS TEMPERATURE CHARACTERISTICS

3.4 Measurement of the Frequency Pulling

3.4.1 *Pulling Range* — The frequency pulling, for the limit value of the load capacitances (trimmer), shall compensate the frequency shifts given by:

a) tolerances on other components of the watch,

b) adjustment tolerance,

c) aging during the economic life of the watch, and

d) residual effects of shocks and vibrations.

3.4.2 *Computation of the Pulling Range (Standard Reference Method)* — The frequency pulling is related to the parameters C_0 and C_1, and is given by the following formula :

$$\Delta f = \frac{C_1}{2\,(C_0 + C_L)}$$

Since the determination of C_0 and C_1 is relatively different, it is preferable to use another method based on the frequency change corresponding to two load capacitances, 12 pF and 20 pF (*see* **3.4.4**).

3.4.3 *Computation of the Motional Capacitance* C_1 (*see* IS : 7962-1975*) — The motional capacitance C_1 is determined by the measurement of the frequency, using two load capacitances C_{L_1} and C_{L_2}, connected successively in series with the crystal unit (*see* Fig. 1).

If $\triangle C_L = C_{L_2} - C_{L_1}$

$\triangle f = f_{L_1} - f_{L_2}$

$\triangle f_1 = f_{L_1} - f_r$

$\triangle f_2 = f_{L_2} - f_r$

$\triangle f_r$ = resonance frequency

f_{L_1} and f_{L_2} are the resonance frequencies of the crystal units in series with C_{L_1} and C_{L_2} respectively.

$$\text{Hence, } C_1 = \frac{2 \triangle C_L}{f_r} \cdot \frac{\triangle f_1 \triangle f_2}{\triangle f}$$

NOTE — The measurements corresponding to the determination of the motional capacitance C_1 take a long time. For quality control in production, one fixed value of C_L could be selected, and the frequency change measured. For the watch-making industry application, the scatter of C_1 is also a very important factor.

3.4.4 *Method for Drawing the* $\triangle f/f$ *Versus* C_L *Curve* — Measure the frequency change corresponding to a load capacitance (C_L) of 12 pF, then of 20 pF.

Mark these values of C_L and $\triangle f/f$ on a graph with logarithmic scale. Draw a straight line through the two points. The line represents the pulling characteristic versus C_L (*see* Fig. 4a).

It is possible to draw a similar straight line based upon the average value of the frequency pulling for a given quantity of crystal units (*see* Fig. 4b).

While theoretically it would be possible to use very low values of load capacitance, for practical cases, a capacitance value inferior to 5pF may be avoided.

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*Methods for measurement for piezoelectric vibrators operating over the frequency range up to 30 MHz.

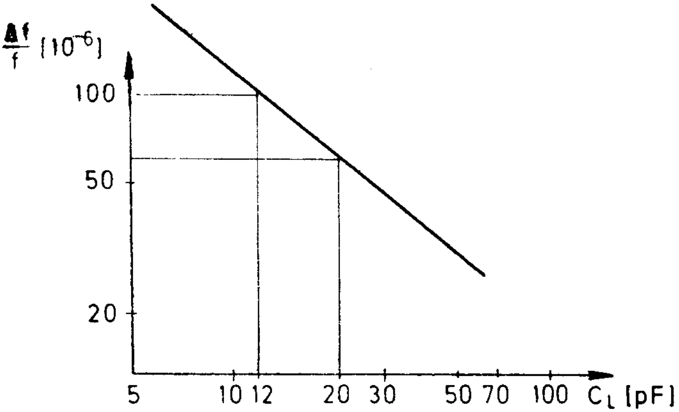

FIG. 4(a) PULLING CHARACTERISTIC

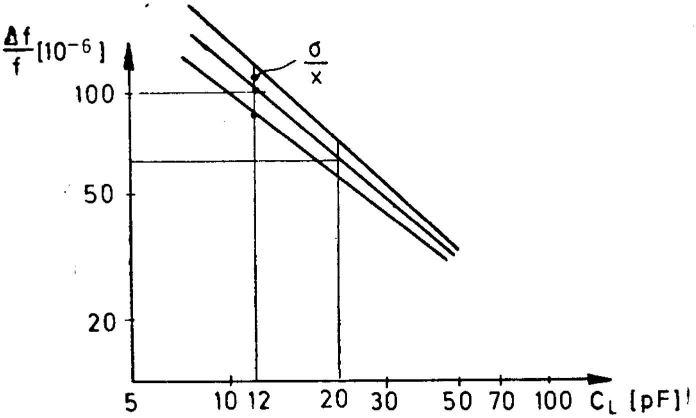

FIG. 4(b) AVERAGE VALUE OF FREQUENCY PULLING

3.4.5 *Quality Factor* — The quality factor Q may be calculated by the following formula:

$$Q = \frac{1}{2\pi f_r R_r C_1}$$

where

f_r = frequency in Hz,

R_r = resistance in ohms, and

C_1 = capacitance in farads.

4. VIBRATIONS

4.0 The method of test may be carried out in accordance with IS : 9000 (Part VIII)-1981*.

4.1 Axes of Vibrations and Mounting

4.1.1 The mounting should not induce residual variations of frequency or resistance.

4.1.2 Sample crystal units are vibrated in the following three perpendicular directions:

a) the direction of vibration parallel to the leads;

b) the direction of vibration perpendicular to a plane containing two pins or wire leads; and

c) the direction of vibration perpendicular to the two abovementioned directions.

4.2 Characteristics of Vibrations — The crystal units shall be subjected to a sinusoidal motion with an amplitude of 0·35 mm, corresponding to a maximum acceleration of 5 g, and with a frequency varying uniformly at one octave per minute between 10 and 150 Hz and returning to 10 Hz. The movement is applied for 2 hours in each direction.

NOTE 1— In the case of testing the mechanical resonance of the suspension of the quartz resonator, it is necessary to extend the frequency range up to 5 000 Hz.

NOTE 2 — If the construction of the resonator is to be tested, the cycle of vibrations shall be applied for 100 days in order to see fatigue phenomena.

4.3 Measurements to be Performed

4.3.1 Prior to vibration, measure the frequency of the crystal unit.

4.3.2 Thirty minutes after the test, again measure the frequency.

---

*Basic environmental testing procedures for electronic and electrical items: Part VIII Vibration.

5. SHOCKS

5.0 The method of test shall be carried out in accordance with IS : 9000 (Part VII/Sec 1)-1979*. The crystal unit to be tested is mounted in a brass holder. The shock is performed using a programmable machine or an impact pendulum tester.

5.1 Preparation

5.1.1 *Shock Parameters* — The machine or pendulum shall be adjusted to obtain the following shock parameters [*see* Fig. 5a]:

a) Acceleration versus time : half sine-wave;

b) Maximum value of acceleration : $A = 5\,000$ g

c) Duration of acceleration : $D = 0{\cdot}25$ ms

corresponding approximately to a free fall from a height of 1 m into hard wood.

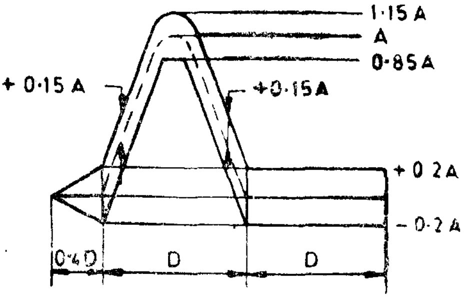

FIG. 5(a) TOLERANCES OF THE SHOCK PULSE

5.1.1.1 If not possible to verify these parameters, refer to **5.2.1**.

5.1.2 The crystal unit is bedded in the centre of the hole in the holder with epoxy resin (equivalent to HYSOL OS 1900). The brass holder has a mass of 30 ± 3g (*see* Fig. 5b).

5.2 Characteristics of the Pendulum Impact Tester — If the device is a pendulum impact tester, it shall be made and used according to the data given in subsequent subclauses.

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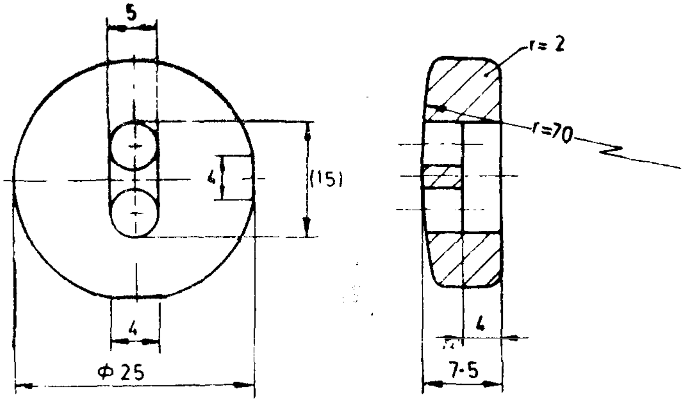
*Basic environmental testing procedures for electronic and electrical items: Part VII Impact test, Section 1 Shock.



Brass plate (Cu 58%, Zn 40%, Pb 2%)

NOTE — In case of a cylindrical crystal unit, the 90° bend in the leads shall be made at least 2 mm from the base.

FIG. 5(b) BRASS HOLDER

5.2.1 *Starting Position of Hammer* — The angle Q, giving the starting position of the hammer (*see* Fig. 6), is derived from the following formula:

$$\text{Sin}\,\frac{Q}{2} = \frac{VT}{4\pi r}$$

where

$V = \sqrt{2gh}$

V is the impact speed corresponding to free fall from a height of h;

T is the period, expressed in seconds;

r is the radius, expressed in metres; and

h is the height, expressed in metres.

The last two values are determined by the manufacturer of the pendulum impact tester.

5.2.1.1 The period T represents the duration, expressed in seconds, of one oscillation of small amplitude (*see* Fig. 7).

5.2.2 *Material and Dimensions of Shoe and Mass of Hammer* — The shoe, which strikes the brass holder, is made of polymethyloxide (for example, Delrin). The total mass of the hammer and shoe is not less than 3 kg. The dimensions of the shoe are shown in Fig. 8.

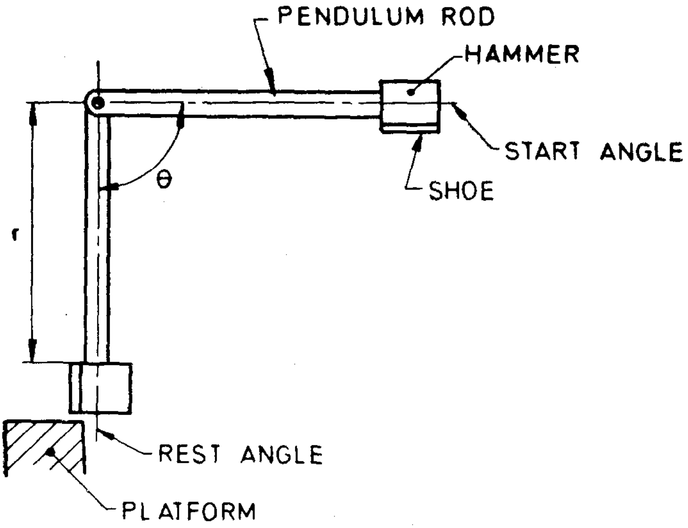


FIG. 6 STARTING POSITION OF HAMMER

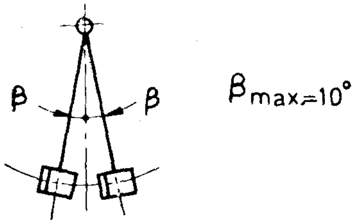


FIG. 7 OSCILLATION OF SMALL AMPLITUDE

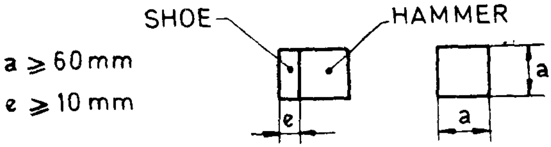


FIG. 8 DIMENSIONS OF SHOE

5.2.2.1 Periodically, the polymethyloxide shoe shall be shifted or ground flat.

5.2.3 *Holder Stopping Device* — After the shock, the brass holder travels freely along its trajectory and is gradually arrested by a device which does not inflict any further shock.

5.3 Procedure

5.3.1 *Position of Brass Holder* — The brass holder shall be laid freely on its horizontal support, for the shock test. The position occupied by the holder shall be such that the shock is produced at the exact instant when the pendulum passes through its point of stable equilibrium.

5.3.2 *Conditions of Shock* — At the moment of impact, the face of the shoe entering into contact with the holder shall be vertical and parallel to the vertical plane containing the axis of oscillation of the pendulum.

5.3.3 *Linear Shocks* — Apply the shocks in the three main axes; the direction is given in Fig. 9.

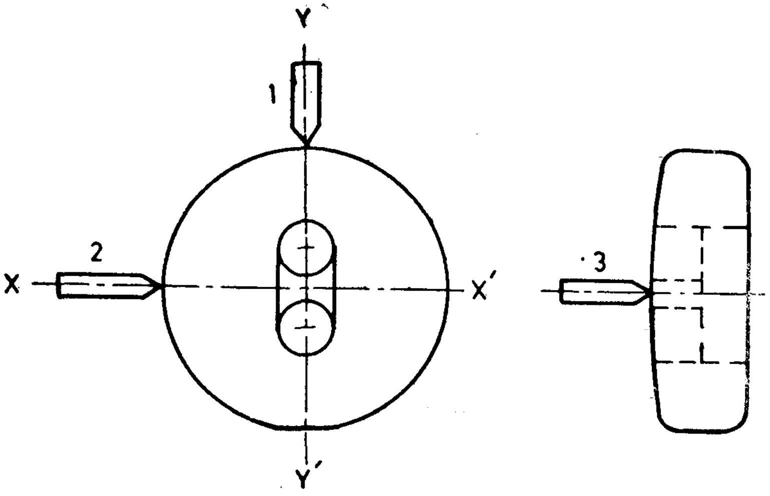


FIG. 9 DIRECTIONS OF LINEAR SHOCK

5.3.4 *Measurements* — All the measurements shall be made when the crystal unit is bedded:

a) measure the frequency and the resistance before the shock;

b) after each shock, leave the crystal unit to rest for at least 30 minutes;

c) measure the frequency; and

d) calculate the average value of the frequency change after the shocks; only the absolute value of the frequency difference is taken into consideration.

6. MAGNETISM : INFLUENCE OF A MAGNETIC FIELD ON THE FREQUENCY

6.1 A crystal unit is placed in a magnetic field for 1 min along each of the three principal directions, and the frequency is measured. The change in frequency during and after the test is noted.

NOTE — The need and the limits for the test are subject to agreement between the manufacturer and the user.

7. MECHANICAL STRESSES ON TERMINATIONS

7.0 The method of test shall be carried out in accordance with IS : 9000 (Part XIX/Sec 1)-1978*.

7.1 Tensile Test on Terminations (Wires or Pins) — A tensile force is applied to the wire according to Table 1; 30 minutes after the test, the results shall be in accordance with the specification.

TABLE 1 APPLIED FORCE FOR TENSILE TEST AND BENDING TEST

NOMINAL CROSS-SECTIONAL AREA (mm^2)	CORRESPONDING DIAMETER (mm)	APPLIED FORCE FOR TENSILE TEST (N)	APPLIED FORCE FOR BENDING TEST (N)
(1)	(2)	(3)	(4)
$S \leqslant 0{\cdot}05$	$d \leqslant 0{\cdot}25$	1	0·5
$0{\cdot}05 < S \leqslant 0{\cdot}07$	$0{\cdot}25 < d \leqslant 0{\cdot}3$	2·5	1·25
$0{\cdot}07 < S \leqslant 0{\cdot}2$	$0{\cdot}3 < d \leqslant 0{\cdot}5$	5	2·5

---

*Basic environmental testing procedures for electronic and electrical items : Part XIX Test for robustness of terminations and integral mounting devices, Section 1 Tensile test.

7.2 Bending of Wire Leads — The wire leads are bent twice through an angle of 90° in opposite directions by applying a force according to Table 1. The change in frequency shall be in accordance with the specified value. Bending is carried out at least 1 mm from the base (*see* Fig. 10).

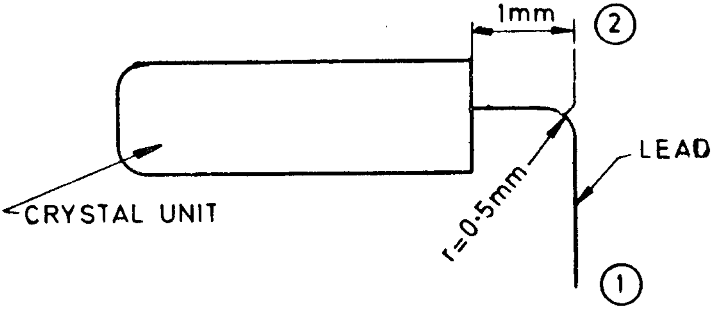


FIG. 10 BENDING WIRE LEADS

7.3 Effect of Support (Mechanical Fixing) — For certain applications, the crystal unit has to be rigidly fixed to a fairly large mass; it is then mechanically coupled to this mass. Some crystal units present a variation in frequency between free and fixed conditions. To detect this effect, it is necessary to carry out the following:

a) Measure the frequency of the crystal unit when free;

b) Fix the unit rigidly to a metal plate weighing not less than 50 g; this may be done by clamping or gluing. If an epoxy resin adhesive is used to fix it, the curing temperature of the adhesive should be in the region of 25°C; and

c) Measure the frequency; the frequency difference shall be less than the specified value.

8. INSULATION RESISTANCE BETWEEN HOLDER AND THE LEADS

8·1 The insulation resistance shall be measured with a dc voltage of 50 ± 5V applied for 1 min ± 5s between:

a) the wire leads or pins:

b) both wire leads connected together and metal parts of the case, if any.

9. METHOD OF FIXING

9.1 Solderability of the Leads — Soldering bath test shall be carried out in accordance with IS : 9000 (Part XVIII/Sec 1)-1981*.

9.1.1 *Test Conditions* — The solder bath shall have a volume sufficient to ensure that the temperature of the solder remains uniform when introducing the termination of the component. It shall be provided with means of maintaining the temperature of the solder at any of the temperatures specified in **9.1.2**.

Precautions shall be taken to ensure uniformity of temperature throughout the mass of the solder within the limits specified in **9.1.2**.

The exposed area of the surface of the solder shall be reduced as far as possible by the use of a sheet of asbestos in order that the component shall not be heated by direct radiation from the bath.

9.1.2 *Procedure* — The conditioning consists of two successive tests for which the temperature of the solder bath is:

Solderability	:	230 ± 10°C	for components and printed wiring applications, or
		270 ± 10°C	for components for normal applications
Resistance to thermal shock	:	350 ± 10°C	for the purpose of **9.1.4** only.

The surface of the bath shall be kept clean and bright and immediately prior to the immersion of any termination or group of terminations a piece of solder shall be dropped into the middle of bath. This solder shall be approximately 12 mm (1/2 in) long, 1·6 mm (1/16 in) in diameter, and of 60/40 tin-lead alloy with a non-activated resin core. No other fluxing shall be used for this test.

NOTE — The term ' non-activated resin ' is intended to mean 'pure wood resin, grade WW' although widely known as 'Water white', it is actually a clean pale amber colour.

9.1.3 *Solderability* — As soon as the added solder has melted, the component termination shall be immersed in the direction of its longitudinal axis into the bath of molten solder at the appropriate test temperature for solderability. The duration of the immersion shall be 2 ± 0·5 s. Wire terminations shall be immersed from the free end up to a point 6 mm (1/4 in) away from the emergence of the termination from the body.

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*Basic environmental testing procedures for electronic and electrical items: Part XVIII Solderability, Section 1 Solderability of wire and tag terminations.

Soldering tags shall be immersed up to a point 3 mm beyond the place intended for the connection of wires or for half their length if this would result in a smaller depth of immersion. The terminations shall be examined for good tinning, as evidenced by free flowing of the solder, with wetting of the terminations.

9.1.4 *Resistance to Thermal Shock* — The terminations shall then be immersed as above, but at 350°C for a period of $3\,^{+1}_{-0}$ s and then withdrawn.

9.2 Other Methods of Fixing — It may also be possible to fix a crystal unit without wire terminations by other methods currently used in micro-electronics and micro-engineering (for example, by bounding, conducting adhesives, etc).

10. SEALING-OVERPRESSURE

10.1 Leak Detection of the Enclosure — The volume of the crystal unit enclosure for the watches is very small, so that the leak which could induce a change in pressure during the time interval corresponding to the warranty may be detected by an industrial apparatus in current use.

10.2 The Leakage Test h_1 may be Reduced to a Measurement of Frequency and Resistance

a) For a crystal unit with big leak, placed at atmospheric pressure 101·3 kPa, the frequency difference is about − 10 Hz.

b) Under similar conditions, the resistance increases by a factor of 3 to 10.

11. MARKING

11.1 Each crystal unit shall be marked legibly and indelibly with the date of manufacture (month and year). Details of markings shall be subject to agreement between the manufacturer and the user.

11.2 The crystal unit may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the ISI Certification Mark may by granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

APPENDIX A

(*Clauses* 3.1.3 *and* 3.2.2)

MEASURING CONDITIONS AND REQUIREMENTS FOR 32·768 kHz QUARTZ CRYSTAL UNITS FOR WRIST WATCHES

Measuring Conditions : Reference temperature : 21 to 25°C

Tolerance of the reference temperature : ± 0·5°C items 1 and 2
± 1°C other items

Drive level : 0·1 W

Load capacitance : 8, 10, 12, 15, 20 pF

Characteristics	*Symbol*	*Unit*	*Requirements*		
			Type (1)	Type (2)	Type (3)
1. Nominal frequency	f	Hz	32768		
2. Frequency tolerance	$\frac{\Delta f}{f}$	10^{-6}	± 20	± 20	± 20
3. Maximum resonance resistance under all operating conditions	R_r	kΩ	60	30	100
4. Minimum motional capacitance	C_1	fF	2·5	2·0	0·8
5. Quality factor	Q	—	*see* **3.4.5**		
6. Turnover temperature	T_0	°C	25 ± 5		
7. Maximum parabolic coefficient	β	$10^{-9}/°C^2$	− 45	− 40	− 40
8. Operating temperature range	—	°C	−10 to +60		

(*Continued*)

	Characteristics	*Symbol*	*Unit*	*Requirements*		
9.	Storage temperature range	—	°C	−30 to +70		
10.	Frequency variation due to vibrations	$\frac{\Delta f}{f}$	10^{-6}	5	3	3
11.	Frequency variation due to shock	$\frac{\Delta f}{f}$	10^{-6}	10	5	5
12.	Frequency variation due to ageing during the first year	$\frac{\Delta f}{f}$	10^{-6}	5	3	5
13.	Frequency variation due to mechanical pressure on terminations	$\frac{\Delta f}{f}$	10^{-6}	3	3	3
14.	Effect of support	$\frac{\Delta f}{f}$	10^{-6}	5	3	3
15.	Insulation resistance at 50 V	—	M Ω	100		
16.	Maximum drive level	*P*	μ W	1	1	1

where : Type (1) = bar flexural,
Type (2) = so-called 'thick' tuning-fork,
Type (3) = so-called 'thin' tuning-fork.